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ANNUAL REPORT

STORM-PETRELS AS INDICATORS OF ENVIRONMENTAL CONDITIONS

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STORM-PETRELS AS INDICATORS OF ENVIRONMENTAL CONDITIONS

I. Summary of Objectives, Conclusions and Implications with Respect to OCS Oil and Gas Development.

A. Summary of Objectives:

To determine if Procellariiformes are ingesting fossil fuel hydrocarbons and develop an inexpensive and reliable method to analyze for petroleum products in their food samples.

B. Summary of Conclusions:

Procellariiformes frequently ingest fossil fuel hydrocarbons while foraging. Digestions slow and birds readily regurgitate food and oil samples when captured either in their burrows or in mist nets. The effects of ingesting small amounts of petroleum products on adults is unknown, but weathered crude oil fed to chicks did not alter culmin, tarsus or wing growth. Dosed chicks gained weight more slowly until they were 21 days old. After 21 days of age there were no differences in weight gains of dosed and control chicks. Dosed chicks fledged an average of three days later than non-dosed chicks. Although this difference is statistically significant, probably it is not biologically significant.

In 1982 food samples were collected from three locations: East Amatuli Island Alaska; St. Lazaria Island, Alaska; and Tatoosh Island, Washington. We collected 875 samples. Of these 53 samples were from

Leach's Storm-Petrels and 8'22 samples were from Fork-tailed Storm-Petrels.

In the laboratory, we have done a series of experiments to determine our ability to recover known amounts of Prudhoe Bay crude oil added to a composite oil sample. Developing a laboratory procedure to quantify petroleum hydrocarbons has been time consuming. Nevertheless, we have found a suitable interval standard to add to oil samples so we can quantify the amount of petroleum present in each sample.

In the process of developing an inexpensive but reliable method for analyzing oil samples, we have been plagued with contamination problems. We found that small amounts of petroleum were sometimes added to the oil sample from the foil liners in the vials. The amounts are small, less than 5% of the hydrocarbons found, but these contaminated samples were scored as positive for fossil fuel hydrocarbons in 1980. We have eliminated this potential source of contamination in our 1982 samples by rinsing all caps with dichloromethane before using them in the field and also by adding teflon liners. While developing the analytical procedure, we tried various grades of reagents and found that only with distilled-in-glass chemicals can we be confident that no source of petroleum is entering the preparation procedure. We have also eliminated several transfer steps to further reduce chances of contamination. We are running two more tests before beginning mass preparation of the samples for analysis.

B. Implications with Respect to OCS Oil and Gas Development

Our field studies have shown that Procellariiformes are ingesting fossil fuel hydrocarbons in what is normally considered a fairly pristine environment--the Gulf of Alaska. Food samples can be collected and analyzed and changes in the amount and frequency of hydrocarbon ingestion can be quantified. This technique could be used to quantify increases in petroleum products in a regional area and thereby correlate these increases with different types of human activity. It could be in some areas that even with more fossil fuel hydrocarbons entering the system, weathering and currents would remove and disperse the petroleum so rapidly that water quality on the regional level would *not* deteriorate.

A monitoring strategy to alert federal agencies to subtle environmental deterioration caused by increases in fossil fuel hydrocarbons will be valuable so that strategies to improve or protect water quality can be determined. Correlations of increased petroleum products with increases in tanker traffic, fishing, runoff, or OCS development will help determine which activity would be most likely to cause a problem.

II. Introduction

To determine subtle changes in the environment and the importance of these changes over a large area is *extremely* difficult. Seabirds, however, maybe a useful tool to use which could monitor inexpensively environmental quality and oceanic conditions. Reproductive patterns of seabirds are known to reflect changes in the environment (Hutchinson 1950, Ashmole 1971, Boersma 1978, Boersma et al. 1980), while foraging seabirds sample the oceans constantly and consequently can be useful indicators of pollutants such as DDT, trace metals, and PCB's (Rise-borough et al. 1967, Anderson et al. 1975, Vermeer and Peakall 1979) . Certain species , such as Brown Pelicans (Pelecanus occidentals) , are good reflectors of fish stocks (Anderson et al. 1980, Sunada et al. 1981).

The purpose of our investigation was to determine whether Procellarii-formes ingest fossil fuel hydrocarbons and then to develop techniques to collect and analyze their stomach contents for petroleum products. Procellariiformes were chosen because they forage over a broad area, feeding intermittently, thereby acting as integrators of the food and pollutants in an area. They feed on small planktonic life, oils, debris and crustaceans in only the top few centimeters of water where many pollutants such as fossil fuels, pesticides and heavy metals also concentrate. Different species of Procellariiformes feed in different water masses. For example, fulmars (Fulmarus glacialis) and Leach's Storm-Petrels (Oceanodroma leucorhoa) feed in the open ocean, but Fork-tailed Storm-Petrels (Oceanodroma furcata) forage along the ocean shelf break or over the continental shelf.

In theory, by sampling an appropriate species, continental shelf water quality could be compared with open ocean water quality. Our research concentrated on Fork-tailed Storm-Petrels because they forage on the continental shelf where increased OCS development and tanker traffic is likely to occur. Because subtle deterioration in water quality will be difficult to detect and analysis of even several water samples will give little information about general water quality, a practical and relatively inexpensive technique to sample a large area of ocean waters would be valuable. Procellariiformes, because they forage broadly, may be a biological monitor of surface water quality.

Task Objectives

1. Continue development and testing of inexpensively reliable methods to analyze food samples from Procellariiformes for fossil fuel hydrocarbons.
2. Collection of stomach contents from storm-petrels.
3. Test the effects of ingestion of weathered crude oil on Fork-tailed Storm-Petrel chick growth and survival.

III. Current State of Knowledge.

Three species of Procellariiformes, Northern Fulmar, Fork-tailed Storm-Petrel and Leach's Storm-Petrel, ingest fossil fuel hydrocarbons. The number of individuals ingesting petroleum increases after a spill. Using gas chromatography, samples can be scored as either having fossil fuel hydrocarbons present or absent. It is more difficult to quantify the amount of petroleum present in each food samples, but these techniques are being developed.

We know that chicks are also ingesting fossil fuel hydrocarbons and that weathered crude oil has few short-term gross morphological or growth effects on Fork-tailed Storm-Petrels.

Samples from several locations in Alaska have been collected to see if the amount and frequency of fossil fuel hydrocarbons ingested by storm-petrels differ --as we expect. This is one means to determine how well Procellariiformes reflect water quality. We predict storm-petrels in the Aleutians to ingest fewer petroleum products than those in the Barren Islands . We expect storm-petrels found on St. Lazaria Island to ingest fewer fossil fuel hydrocarbons than those around the Barren Islands. Samples from Leach's Storm-Petrels and Fork-tailed Storm-petrels found at the same location will be compared to test whether the prediction that Leach's Storm-Petrels ingest fewer hydrocarbons than Fork-tailed Storm-Petrels is *correct.* We would like to gather samples from storm-petrels along the Californian coast because we believe these birds are encountering and ingesting more hydrocarbons than from any other area along the coasts of western United States. Funding has not been available to conduct this test.

The three years' of samples from the Barren Islands will be used to assess whether the rate or amount of hydrocarbons ingested by Fork-tailed Storm-Petrels has changed. In 1980 the Coast Guard reported five pollution events within 200 km of the Barren Islands. In 1981 there was one spill reported within 200 km of the Barren Islands, and none in 1982. Therefore we predict that the incidence of samples positive for fossil fuel hydrocarbons will decrease between 1980 and 1982.

IV. Study Area.

A. Field trip schedule

We were in the field between June 1982 and September 1982. USFWS provided equipment (outboard motors, zodiacs, and some field equipment for portions of this study. Logistical support was chartered out of Homer, Alaska. Flynn's Barge Service transported personnel and equipment to and from the island (E. Amatuli) on June 15 and August 30, 1982. Maritime Helicopters reprovisioned the camp and transported personnel in June, July and August 1982. Table 1 shows the itinerary and personnel present during the field season in Alaska.

B. Scientific Party

1. Dr. P. Dee Boersma, Associate Professor
   University of Washington
   Institute for Environmental Studies and Department of Zoology

2. Emily Davies, Research Technologist
   University of Washington
   Institute for Environmental Studies

3. V. Louden, 5th year student
   University of Washington
   Laboratory Assistant

4. T. Friedman, 3rdyear student
   University of Washington
   Laboratory and field assistant

5. C. Sanders, 1st year student
   University of Americas
   Berkeley, California

6. S. Blyth, High School Senior
   Roosevelt High School
   Seattle, Washington

Table 1. ITINERARY for 1982. Barren Islands, Alaska

Date	Personnel	Location
6/14/82	Dr. P. Dee Boersma E. Davies, T. Friedman, V. Louden, C. Sanders	Seattle *to* Homer
6/15/82	same as above	Home to E. Amatuli by LCM "Nanuk''
6/24/82	Dr. P. Dee Boersma	E. Amatuli to Homer by Maritime Helicopters
7/ 1/82	E. Davies, T. Friedman; V. Louden, C. Sanders	E. Amatuli to Sugarloaf and return by zodiac
7/ 8/82	same as above	E. Amatuli to W. Amatuli and return by zodiac
7/20/82	P. Dee Boersma and S. Blyth	Home to E. Amatuli
7/20/82	T. Friedman	E. Amatuli to Homer by Maritime Helicopters
7/24/82	Boersma, Davies, Sanders and Louden	E. Amatuli to W. Amatuli
8/ 3/82 .	Boersma, Davies, Louden, C. Sanders, S. Blyth	E. Amatuli to Ushaget and return by zodiac
8/ 4/82	Louden and Sanders	E. Amatuli to Sugarloaf and return by zodiac
8/ 8/82	Boersma, Davies	E. Amatuli to Kenai by fishing boat
8/30/82	V. Louden, C. Sanders, S. Blyth	E. Amatuli to Homer by LCM "Nanuk"

V. Methods.

A. Number and Types of Samples

Food samples were collected by removing storm-petrels from their burrows or from a mist net and holding their beaks over a Nalgene funnel (Table 2). When the bird regurgitated, the food sample was rinsed down into a scintillation vial with nanograde dichloromethane. At the same time we banded birds with stainless steel bands, weighed (± 1 gm) and measured them. Vials were labeled with the band number, date, number of regurgitates and color coded. Samples were stored at approximately 10″C.

Samples were collected between April and September at three sites: 2 in Alaska and one in Washington (Table 3). We collected 875 samples in 1982: 53 samples were from Leach's Storm-Petrel and 822 samples were from Fork-tailed Storm-Petrels (Table. 3). This compares with 698 samples collected at 5 sites in 1981 (Table 4).

B. Chick Dosing Experiment

A total of 68 Fork-tailed Storm-Petrel chicks were orally dosed with weathered Prudhoe Bay crude oil. This oil was "weathered" in the laboratory by bubbling air through it for approximately 38 hours until its volume was reduced by one-fourth. Twenty-six chicks were given a single 0.1 ml dose of oil; 30 chicks were dosed twice, at seven day intervals; and 12 chicks were dosed weekly (Table 5).

Chicks were first dosed between the ages of 6 to 28 days. The means and ranges for age at first dosing are shown in Table 6.

Sixty-one control chicks were selected from nearby burrows with similarly aged chicks. No sham-dosing was conducted. Growth rates for weight, culmin, wing and tarsus were" measured every four days.

1982 OIL SAMPLES: ACQUISITION METHODS--EAST AMATULI ISLAND, ALASKA

	June	July	August	September	Totals
Mist Net Captures	0	36	166	0	202
Retrieval from Burrows	343	203	0,	0	546
Totals	343	239	166	0	748

Table 2. Methods of acquisition for regurgitates, 1982 East Amatuli Island, Alaska.

1982 OIL SAMPLES: SPECIES/LOCATION AND DATES

		April	May	June	July	August	September	Totals	
East Amatuli Is., Alaska	FTSP *	0	0	343	239	166	0	748	748
	LSP **	0	0	0	0	0	0		
St. Lazaria Is., Alaska	FTSP	0	0	0	41	0	0	41	79
	Em	0	0	0	38	0	0	38	
Tatoosh Is., Washington	FTSP	17	16	0	0	0	0	33	48
	LSP	5	10	0	0	0	0	15	
Total		22	26	343	318	166	0	875	

Table 3. 1982 Regurgitates classified by species, location and date of acquisition.

* Fork*tailed Storm-Petrel
** Leach's Storm-petrel

1981 OIL SAMPLES: SPECIES/LOCATION AND DATES

Location		Jan.	Feb.	May	June	July	Aug.	Sept.	Totals	
East Amatuli Is., Alaska		0	-0-	-0-	203	254	120	2	579	579
	LSP	0	0	0	0	0	0	0	0	
St. Lazaria Is., Alaska	FTSP	0	0	0	0	16	15	0	31	45
	LSP	0	0	0	0	10	4	0	14	
Aleutian Is., Alaska	FTSP	0	0	0	0	26	0	0	26	34
	LSP					8			8	
Laysan Is., Hawaii	sooty s-P	13	1	0	0	0	0	0	14	14
Tatoosh Is., Washington	FTSP	0	0	11	0	2	0	0	13	26
	LSP	0	0	13	0	0	0	0	13	
Totals		13	1	24	203	316	139	2	698	698

Table 4. 1981 Regurgitates classified by species, location and date of acquisition. FTSP = Fork-tailed Storm-Petrel and LSP = Leach's Storm-Petrel.

Dosing Experiment - Barren Islands, Alaska 1981

Table 5. Number of Fork-tailed Storm-Petrel chicks dosed on East Amatuli Island with weathered Prudhoe Bay crude oil.

Number of chicks dosed	1 dose	2 doses	weekly	Total
Areas A B E Z	15	15	7	37
Areas D and D_1	11	15	5	31
Total	26	30	12	68

Table 6. Mean age when Fork-tailed Storm-Petrel chick was first dosed with 1.0 ml weathered Prudhoe Bay crude oil.

Burrow location on East Amatuli Island	Mean age of chicks 1 dose	Mean age of chicks 2 doses	Mean age of dosed chicks weekly	Average age when dosed (total)
Areas A B E Z	11 (range 7-20)	16 (range 8-28)	15 (range 10-20)	13
Areas D and D_1	11 (range 6-17)	9 (range 7-13)	10 (range 7-14)	10
All dosed chicks (total)	11	12.5	12.5	12

c. Analysis of samples

While collecting food samples, a blank or control sample is periodi-tally collected. Dichloromethane is rinsed down the funnel into a sample vial and labeled. The blank is treated and prepared as if it were a food sample, although it lacks the storm-petrel's regurgitate. The general field and laboratory procedure is shown in Figure 1. In the laboratory we attempted to develop a quick screening procedure to crudely separate samples with fossil fuel hydrocarbons from samples without them. Because fossil fuel hydrocarbons phosphoresce we used thin layer chromatography to separate fractions and then held the chromatography strip under the backlight. Unfortunately, the biological hydrocarbons also proved to be phosphorescent substances so that crude screening using this method proved unreliable and was eventually abandoned.

Not all samples will be analyzed because of expense. Normally we collected more than 30 samples every 5 days while on East Amatuli Island. Fifteen samples at 5-day intervals have been chosen from the available samples for analysis. Samples chosen represent a mixture of all the color types, from clear to dark orange (See Section VI-A). The same procedure of choosing a broad range of colored samples and choosing samples from one day is being used to determine which samples will be analyzed from the other locations.

A technical description of the quantitation methodology is provided in Appendix A.

D. Natural History

We continued studies begun in 1976 on growth rates, nesting success

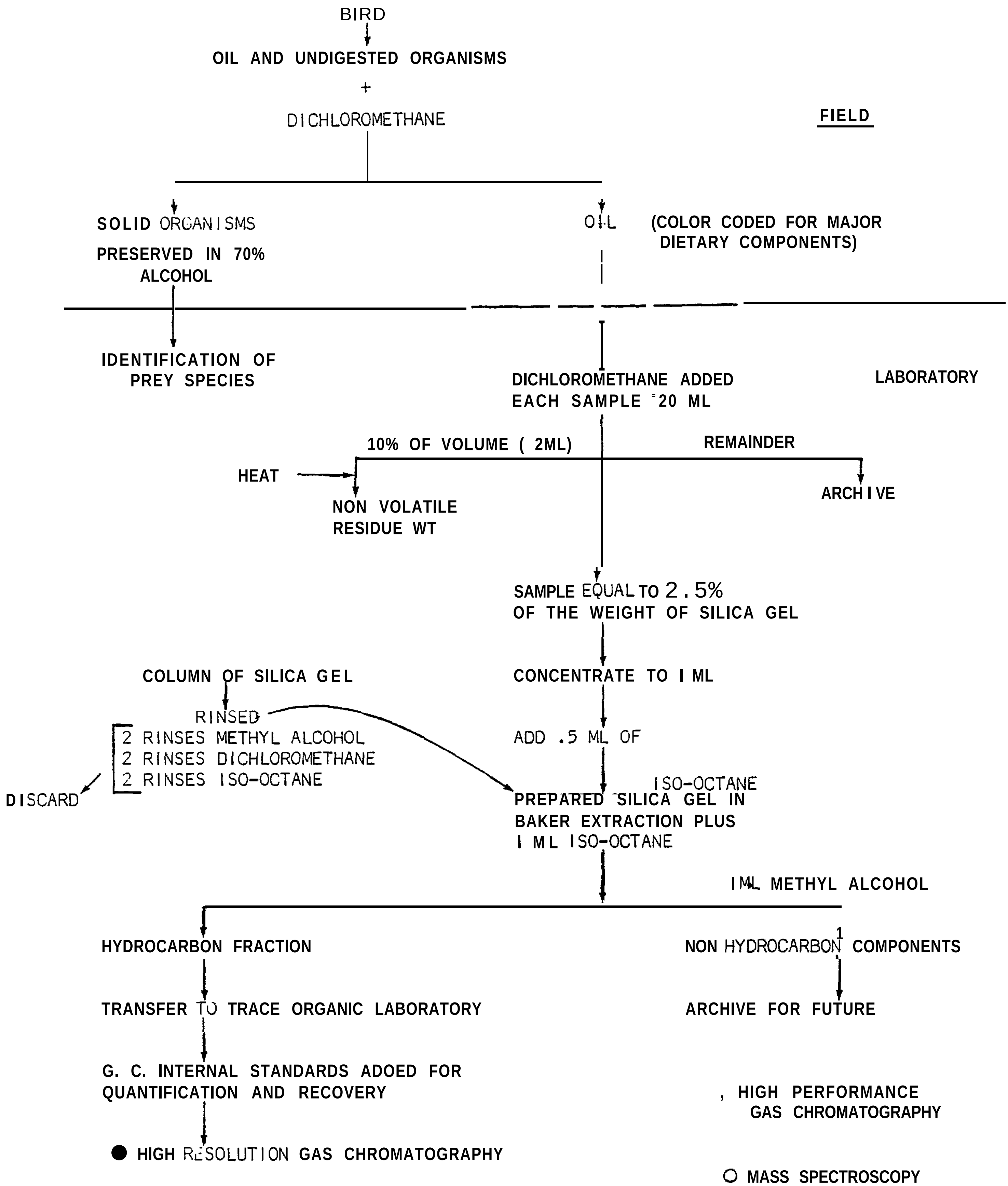


Figure 1. PROCEDURE FOR FOOD SAMPLE ANALYSIS

and mate and burrow fidelity of Fork-tailed Stem-Petrels together with a less intensive monitoring of a Tufted Puffin (Lunda cirrhata) colony. These data represent the longest continuosu record of a seabird colony in Alaska. Its value is in determining what is the natural variability in growth and breeding success

VI. Results .

A. Food Samples

Samples varied in color from clear to dark orange. Yellow was the most common color in 1981 and medium orange in 1982 (Tables 7 and 8). The color of the food sample reflects the bird's diet, particularly whether crustaceans have been consumed. .

Residue weights indicate that most samples are small, less than 0.4 g/sample. However, some samples have more than 3 grams of oil. Clear, light orange and green samples were associated with small residue weight while yellow, medium orange and dark orange indicated large samples (Table 9). This is consistent with our field observations: that light samples generally had little regurgitate. The green color seems to be from the bird regurgitating a small amount of bile with the food sample.

B. Sample Analysis

When Hawaiian food samples were gathered, the extreme heat of the environment evaporated the dichloromethane. Sample vials were repeatedly opened and more dichloromethane was added. Upon analysis we found the blank (Figure 2) and the samples were extremely dirty. Investigating potential sources, we found a small fraction of the contamination could have come from the vial caps that are lined in foil.

In any case, this contamination was minor and could account for less than 5% of the hydrocarbons found. Nevertheless, we eliminated this source of petroleum in subsequent samples by washing all vial caps in a rinse of hexane. The caps were then lined with teflon to seal the sample from the cap. How the Hawaiian samples became contaminated is unknown, but we suspect that storing of dichloromethane in polypropaline bottles and the subsequent opening and refilling of vials caused the problem.

Upon running a small batch of samples from Tatoosh Island, we found cent aminat ion. We began testing all chemicals and breaking down the sample preparation into component parts. Hexane, toluene and methanol were contaminated with hydrocarbons (Figure 3}. These chamicals were not distilled in glass so we now use chemicals of higher purity and grade.

We also found that if chemicals sit in polypropaline squeeze bottles they become contaminated. Consequently, we now use only glassware rinsed in hexane to hold chemicals.

Disposable glass pipettes are used to transfer chemicals to *reduce the* opportunity for contaminate introductions. The number of transfers of the sample during preparation has been reduced and the number and amount of chemicals introduced has been decreased. The Baker extraction system was purchased so that 10 samples can be directly ejected into vials and methanol, dichloromethane and iso-octane are added. To reduce the amounts and types of chemicals used and to eliminate transfers has been time consuming.

1981 OIL SAMPLES: COLOR CLASSIFICATION

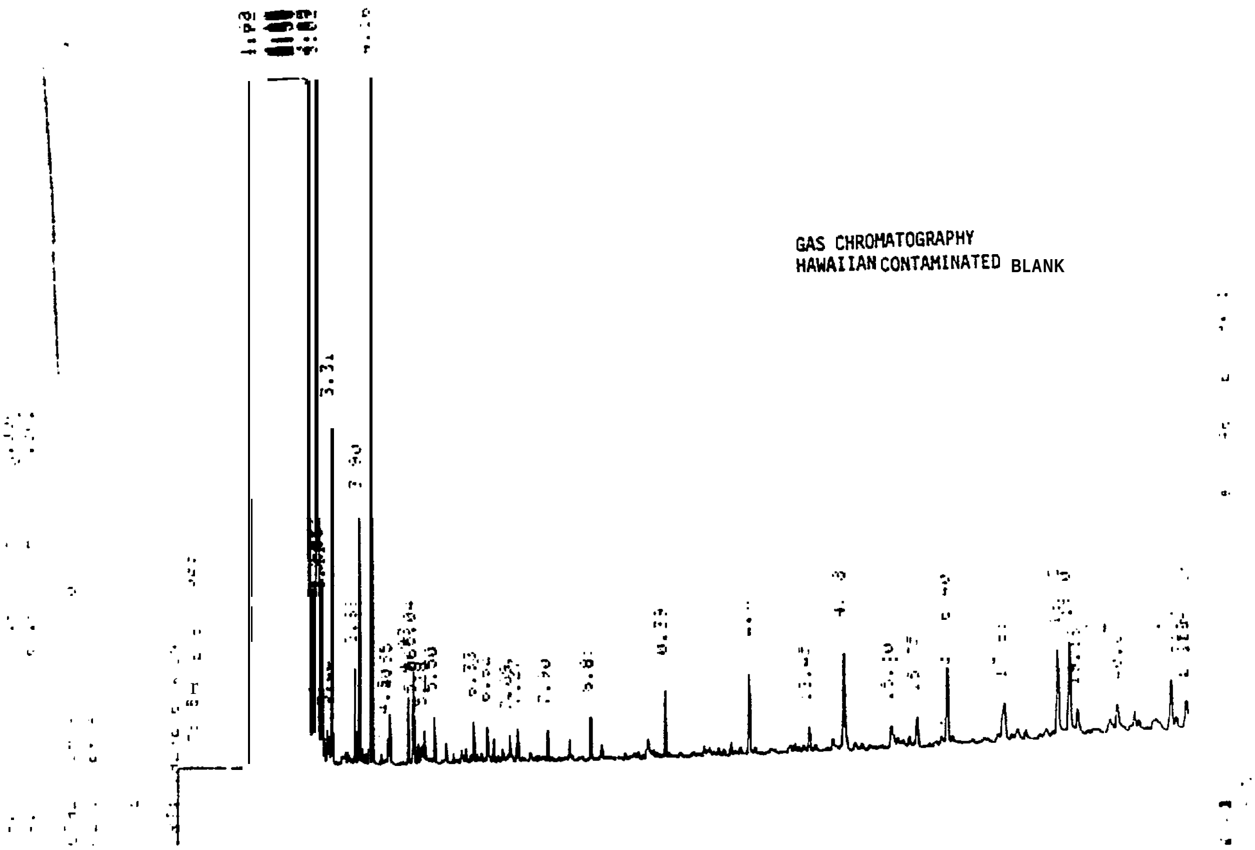
Location	Dk. Orange	Med. Orange	Lt. Orange	Clear	Yellow	Green	Totals
East Amatuli Is., Alaska	51	166	76	54	229	3	579
St. Lazaria Is., Alaska	14	17	0	0	14	0	45
Aleutian Is., Alaska	2	14	13	0	5	0	34
Laysan Is., Hawaii	0	2	1	0	11	0	14
Tatoosh Is., Washington	2	8	8	4	4	0	26.
Totals	69	207	98	58	263	3	698

Table 7. 1981 Regurgitates classified by color and location of acquisition,

1982 OIL SAMPLES: COLOR CLASSIFICAT ION

ɔcation	Dk. Orange	Med. Orange	Lt. Orange	Clear	Yellow	Green	Totals
ıst Amatuli [s., Alaska	99	359	166	42	80	2	748
t. Lazaria Is., Alaska	2	48	21	0	8	0	79
atoosh Is., ashington	0	22	21	2	3	0	48
'otals	101	429	208	44	91	2	875

Table 8. 1982 Regurgitates classified by color and location of acquisition.



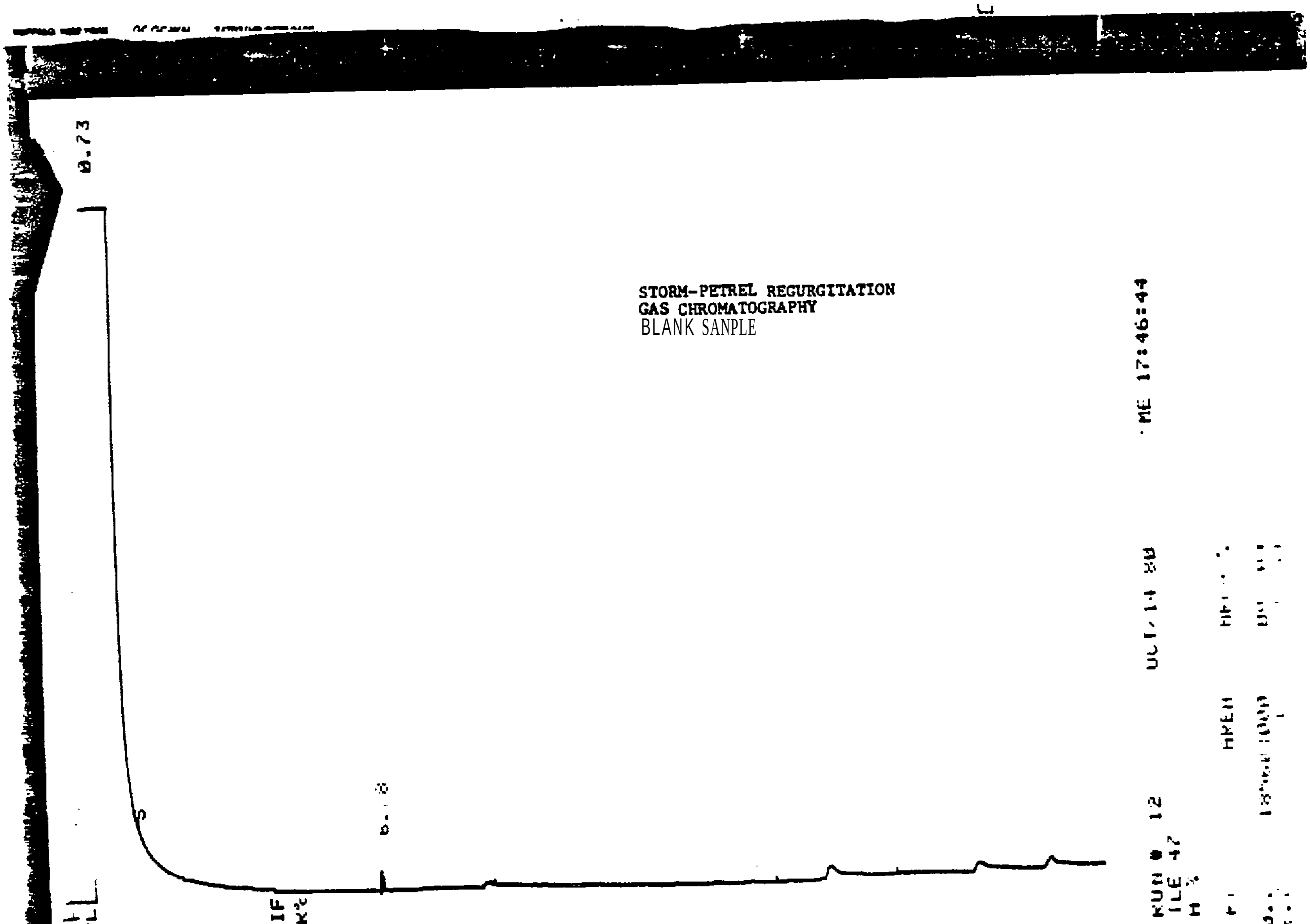


Figure 2. Comparison between a contaminated blank from the Hawaiian Islands and a clean blank from the Barren Islands.

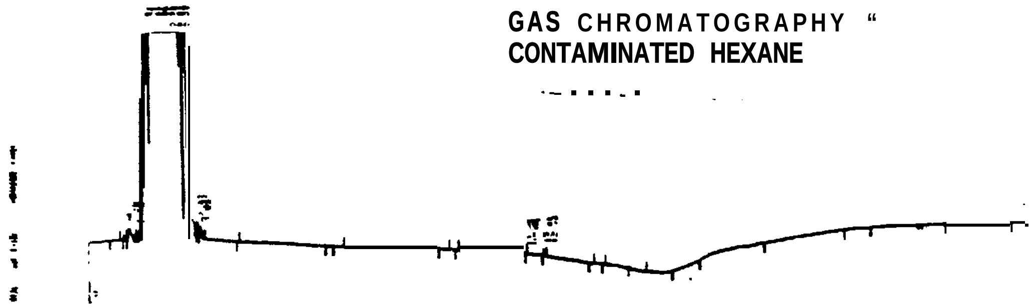
At the same time that the sample analysis procedure has been modified, we ran a series of experiments to determine our accuracy in recovering known amounts of Prudhoe Bay crude oil. With an interval standard added to each sample, the amount of petroleum product present in each sample can be quantified. We ran one sample batch using the analytical procedure and found that dichloromethane must be used in rinsing the silica gel column because the methanol and iso-octane do not mix. We will run one more small sample batch before starting mass sample analysis. Batch processing should reduce the cost and variability in analysis.

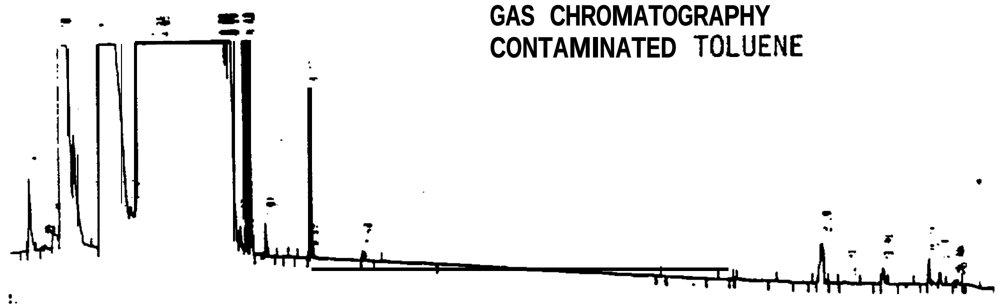
C. Chick Dosing Experiment

The direct lethal impact of oil spills on adult seabirds is well documented. A number of studies have investigated the impacts of chronic, low-level oil pollution on marine birds, especially on adult reproductive success, egg matchability and chick growth rates (See Part 111 of Wheeler 1982).

Twenty-one chicks dosed with weathered crude oil fledged during the 1981 breeding season. Only one dosed chick died, and this chick was growing poorly before it was dosed. It probably died from starvation instead of from the oil. The remaining 46 dosed chicks were still in their burrows whenwe left the island andwe believe, based on their appearance, they probably all fledged.

Bill, tarsus and wing growth of chicks dosed once, twice, or weekly were similar. The growth of chicks on north facing and south facing





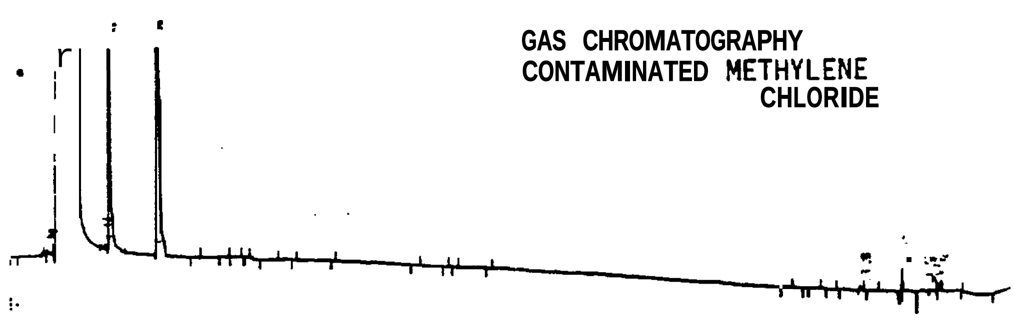


Figure 3. Contaminated chemicals used in laboratory procedure. Note the regular pattern of fossil fuel hydrocarbon peaks.

slopes were similar. Therefore, dosed chicks, regardless of the number of times they were dosed or where they lived, were combined for further analysis.

The mean age at fledging was significantly longer for combined dosed chicks than for control chicks ($t = 2.82$, $df = 45$; $p = .05$). Dosed chicks fledgedon average at 62.8 days whereas control chicks fledged early at 60.4 days of *age.* All other measurements of size at fledging (i.e., mean weight, culmin length, wing length, tarsus) were similar.

Growth rates of dosed versus control chicks were compared. Dosed chicks from 1 to 21 days of age gained significantly less weight than control chicks (analysis of co-variance: $F = 4.21$; df 1, 39; $P = .05$). Both dosed and control chicks gained weight similarly between 22 and 51 days of age. The bill, wings and tarsus of dosed and control chicks grew similarly.

D. Natural History

Fork-tailed Storm-Petrel chicks gain weight following one of two curves of similar shape. Whether they gain weight relatively rapidly or slowly depends on the year. In 1976, 1978, 1980, and 1982 chicks gained weight significantly faster than in 1977, 1979, and 1981. We believe that the number of sunny days may explain this pattern because in 1980 we found chicks 21 days of age or older on south facing slopes grew more rapidly than similarly aged chicks on north facing slopes. Knowing the range of variability is essential to determine the impact of perturbations such as OCS development.

We have previously reviewed the literature showing that Fork-tailed Storm-Petrels and Leach's Storm-Petrels forage in different water masses .(Wheelwright and Boersma 1979). Recent observations further substantiate that Fork-tailed Storm-Petrels forage closer to land than do Leach's Storm-Petrels (Forsell and Gould 1981). During stormy weather in 1981 and 1982 we observed Fork-tailed Storm-Petrels foraging within one-quarter mile of East Amatuli. On three occasions when the weather was somewhat rough and overcast we saw Fork-tailed Storm-Petrels foraging close to the Barren Islands. In contrast, on clear and calm days from 1976 through 1982 we never saw any Fork-tailed Storm-Petrels on our zodiac trips around" the islands. Fork-tailed Storm-Petrels arrive on the island earlier at night than do Leach's Storm-Petrels which is consistent with the observations that Fork-tailed Storm-Petrels forage closer to land (Figure 4). This same pattern (of earlier arrival times of Fork-tailed Storm-Petrels compared to Leach's Storm-Petrels, quantified on Tatoosh Island, WA.), was observed at St. Lazaria Island, Alaska. On East Amatuli Island only Fork-tailed Storm-Petrels are present, but they still follow the same pattern of arriving around 2000 hours or after dark and departing by 0200 or before dawn. Thus the presence of another storm-petrel does not appear to have any impact on arrival time.

Both species of storm-petrels throw up oil and partly digested fish and crustaceans when captured. Only 29% of the Leach's Storm-Petrels captured on Tatoosh Island, Wa., ejected oil (N-997), but S6% of the Fork-tailed Storm-Petrels did (N = 338). There is not only a significant difference between species in the frequency that they threw up ($X^2 = 76.4$; $p^= .001$) but Fork-tailed Storm-Petrels throw up more oil.

Because of these differences in regurgitant volumes some species may be, therefore, difficult to use as samplers of the environment.

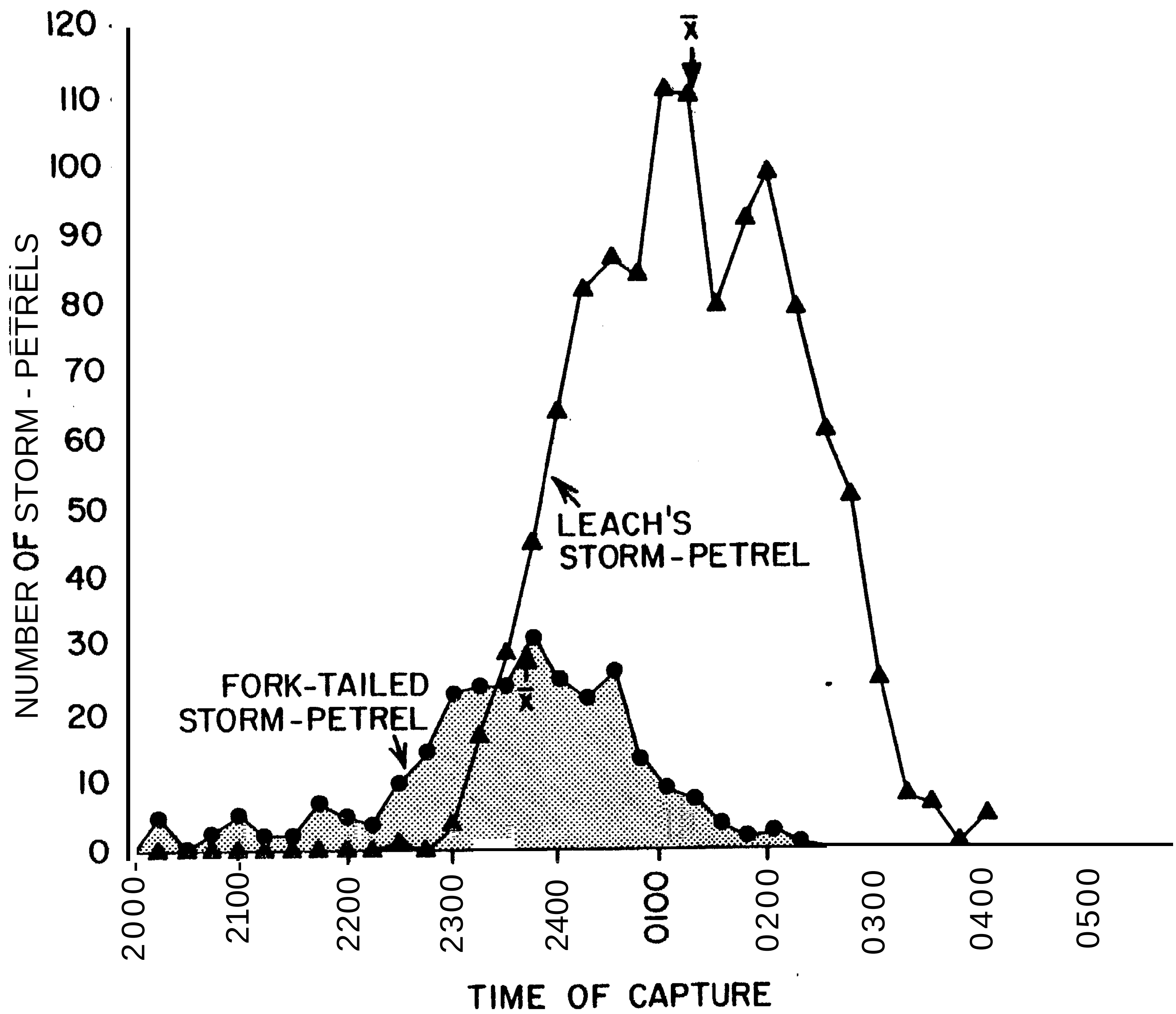


Figure 4. Arrival time of mist netted storm-petrels on Tatoosh Island, Washington
Mean arrival time is indicated by $\bar{X}$.

The studies mentioned above suggest that Fork-tailed Storm-Petrels may be doubly affected by oil pollution in the marine environment: first by the direct physiological stress effects of ingesting oil, and secondly, by their parents' reduced abilities to provide food for their young because of oil-ingesting related impacts on the adults themselves. These impacts may ultimately affect the chicks' abilities to reach reproductive age, even though they do *not* immediately cause mortality. The long-term impacts could be reduced recruitment and a subsequent decline in stem-petrel populations.

Because our field results were comparable to other studies, we did not repeat this experiment. We have three dosed chick specimens which could be examined for physiological abnormalities. An elaborate physiological experiment was beyond the scope of this project.

Petroleum products are, and probably will become, the most common toxic substance released into the oceans. Petroleum currently makes up nearly 95% of the bulk hazardous cargo moved in the northeastern Pacific (Clark 1976). In fact, marine transportation accounted for approximately 35% of the petroleum hydrocarbon entering the ocean in 1973 (M'Gonigle and Zacher 1979). With OCS development, tanker traffic, the amount of oil entering the ocean should increase. We expect to see the seasonal impact of oil in Alaskan water by looking at food samples at the beginning and end of the summer. Procellariiformes may prove to be a group of organisms that can be used to assess regional water quality and , as well, long-term changes in the environment.

It is clear, however, that some species will be easier to gather food samples from than others. Fork-tailed Storm-Petrels readily regurgitate, but Leach's Storm-Petrels are less reliable. Sooty ShearWaters (*Puffinus griseus*) do not throw up (personal observations and Grau, pers. comm.). Fulmers, however, regurgitate as readily as Fork-tailed Storm-Petrels. Information on general natural history will be important when choosing a Procellariiform as a potential reflector of regional water quality.

VIII. Needs for Further Study.

There are two areas that could add significantly to our data base. One is whether water quality in relation to fossil fuel hydrocarbons in the northern Gulf of Alaska and lower Cook Inlet is remaining constant. As the Cook Inlet field is depleted, we might expect less oil to enter the marine environment thereby reducing petroleum products in this area. Food samples from storm-petrels taken from the Barren Islands in June of each year could alert us to any apparent trends.

Secondly, storm-petrels off the California Coast are exposed to heavy tanker traffic, OCS development and natural seeps. What are their levels of fossil fuel hydrocarbons and do Ashy Storm-Petrels (Oceanodroma homochroa) have more than Leach's Storm-Petrels? Do Ashy Storm-petrels in the Santa Barbara Islands ingest more fossil. fuel hydrocarbons than those around San Francisco Bay? Collecting samples from these areas would help determine the relative ability of storm-petrels to reflect changes in abundance of petroleum products in the ocean.

APPENDIX A

QUANTITATION OF FOSSIL FUEL HYDROCARBONS IN PETREL STOMACH SAMPLES

The most easily discernible component of the gastric samples that might be of fossil fuel origin is the n-alkane series of peaks from n-decane through n-henitricontane. Although other components of fossil fuels are more exclusively limited to fossil fuel sources (such as some isoprenoid or aromatic compounds), these are not as suitable due to lower abundance and to differential losses in petroleum distillation processing. Therefore, the n-alkane series was selected as the initial indicator of fossil fuel content. A series of experiments was conducted to establish the recovery of these compounds through the sample preparation scheme and to allow quantitation. A composite "background" sample matrix was created by combining several samples from the first years' samples that showed no detectable n-alkane petroleum contamination. This matrix was spiked with Prudhoe Bay crude oil at 0.5, 1.0, 2, 5, and 10 mg/ml. Duplicate aliquots were fractionated using the sample preparation scheme and quantitated against a dilution response curve for each component (dodecane through triacontane). Fractions collected after the n-alkane fraction were also examined to ensure no losses through chromatographic tailing during sample preparation. These experiments established that individual alkanes could be quantitated with high linearity, and with high recovery. However, episodes of variability in the column chromatography resulted in some samples having very high backgrounds. This was attributed to variation in column activity. To overcome this problem, it was determined that commercial silica gel separation cartridges (Baker preparation columns) could be used in place of homemade silica columns. This change was incorporated and greatly reduced the time required for chromatographic preparation--in addition to providing better reproduceability.

Using this new preparation method, a 5 mg/ml sample of Brudhoe Bay crude oil was prepared and the recoveries for C-11 through C-32 n-alkanes plus pristane and phytane were recovered with an average recovery of 94.1%. (See Table 1). Some losses below C-14 and above C-30 were observed, presumably resulting from volatilization and adsorption respectively. Table 2 and Figure 1 present the calibration mixture used for quantitation. Only the n-alkane components will be computed, but the branched alkane peaks and hexamethylbenzene will be used for recovery determinations. Acenaphthene is used as an internal standard.

Table 1: Recovery of Alkane Hydrocarbons (Prudhoe Bay Crude) by Commercial Silica Gel Cartridges.

Compound	Mass Concentration (ppm)	Retention Time (minutes)	Percent Recovery from single/ml Of crude oil
C_{11} n-Alkane	20	6.72	65
C_{12} n-Alkane	20	9.03	69
C_{13} n-Alkane	20	11.58	60
3-Methyl Tridecane	2 0		
C_{14} n-Alkane	20	14.16	86
Acenaphthene (internal standard)	50	16.40	
C_{15} n-Alkane	20	16.70	95
3-Methyl Pentadecane	22.5		
C_{16} n-Alkane	20	19.15	106
C_{17} n-Alkane	20	21.s1	110
Pristane	20	21.65	109
3-Methyl Heptodecane	23.8 "		
C_{18} n-Alkane	20	23.72	121
Phytane	20	23.92	117
C_{19} n-Alkane	20	25.55	111
C_{20} n-Alkane	20	27.08	114
C_{21} n-Alkane	20	28.41	106
3-Methyl Henicosane	19.3		
C_{22} n-Alkane	20	29.59	107
C_{23} n-Alkane	20	30.66	93
3-Methyl Tricosane	20		
C_{24} n-Alkane	20	31.66	92
C_{25} n-Alkane	20	32.58	91
C_{26} n-Alkane	20	33*45	85
C_{27} n-Alkane	20	34.33	88
C_{28} n-Alkane	20	35.26	90
5-Cholestane (steroid)	20		
C_{30} n-Alkane	20	37.45	82
C_{31} n-Alkane	20	38.80	73

Table 2

Operating Conditions for n-Alkane Hydrocarbon Chromatography

Machine: Hewlett Packard 5880A
Gases : Helium carrier gas, Nitrogen Makeup
Column : SE-54 (Normal Phase) Fused Silica Capillary Column J&B)
Length : 30 Meters, .25 m Film Thickness, .32mm ID

Operating Parameters

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OVEN TE    30°C   SETPT=80°C   LIMIT=405°C
   EQUIB TIME = 3.00 MIN

OVEN TEMP PROFILE:
   INITIAL VALUE = 80°C
   INITIAL TIME = 1.00 MIN
   LEVEL 1
      PRGM RATE = 5.00°C/MIN
      FINAL VALUE = 190°C
      FINAL TIME = 0.00 MIN
   LEVEL 2
      PRGM RATE = 10.00°C/MIN
      FINAL VALUE = 295°C
      FINAL TIME = 8.00 MIN
   POST VALUE = 325°C
        TIME = 5.00 MIN

        EMP=300°C   SETPT=300°C   LIMIT=405°C
      EMP=0°C   SETPT=50°C(OFF)   LIMIT=405°C
        EMP=250°C   SETPT=250°C   LIMIT=405°C
INJ 2 TEMP=0°C   SETPT=50°C(OFF)   LIMIT=405°C
AUX 1 TEMP=0°C   SETPT=250°C(OFF)   LIMIT=405°C
AUX 2 TEMP=0°C   SETPT=50°C(OFF)   LIMIT=405°C

DEVICE 2: GC TERMINAL 1
   SIGNAL = D
   PLOT = ???
   CHART SPEED = 0.70 CM/MIN
   ATTN = 2↑2
   %OFFSET = 10
   ZERO = 14.11

DETECTOR B: FLAME IONIZATION
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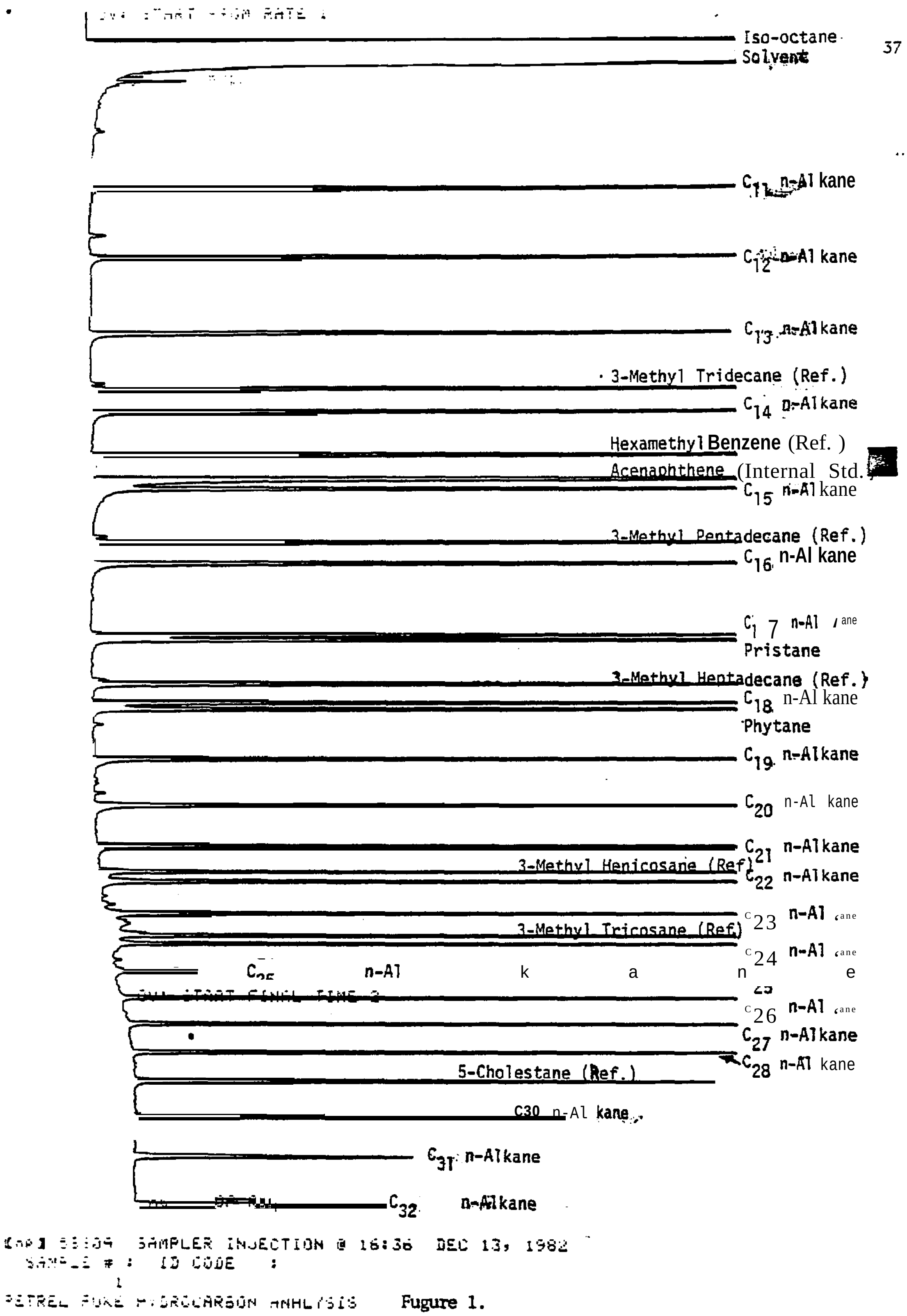

Fugure 1.

Standard courtesy of Robert Barrick,
Dept. of Oceanography, Univ. of Wash.

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